THE WEATHER AND CIRCULATION OF JULY 1959

The Second Consecutive July with an Unusual Circulation Pattern

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1. INTRODUCTION

For the second successive July [2] many of the troughs and ridges on the 700-mb. 30-day mean map (fig. 1) were not in the climatologically preferred locations indicated in studies made by Klein and Winston [6]. This was especially true of the western sectors of the Northern Hemisphere in July 1958, and again this July an abnormal trough appeared over the central United States. In the eastern and western coastal areas, where weak ridges were observed, the circulation was more anticyclonic than usual. This regime was associated with generally light precipitation in the West but heavy rainfall in several large areas east of the Rocky Mountain States (figs. 2, 3). Rainfall from tropical cyclones Cindy and Debra augmented the total precipitation in Texas and along the east coast. Temperatures averaged below normal in most of the Central and Southeastern States and were above normal in most other regions, with record heat reported in the Far Southwest (fig. 4).

2. 30-DAY AND 5-DAY MEAN CIRCULATIONS

The July circulation at the 700-mb. level over the western Northern Hemisphere (fig. 1) was one of small amplitude, and many of the troughs and ridges were out of phase with those on the July normal chart [9]. The normal July troughs along both the east and west coasts of North America were apparent this year only in eastern Canada and possibly along the California coast, where a trough remnant was discernible. More interesting is the unusual circulation in other areas. The ridges in the western Bering Sea, western United States, and north-central Atlantic, and the troughs in north-central Pacific, central United States, and northern Atlantic were all in climatologically infrequent areas [6]. The data of [6] show that 30-day mean ridges were extremely rare in the western Bering Sea in the Julys from 1933 to 1955, and in the northern latitudes over eastern Siberia no ridges at all were observed during this period. The 30-day mean ridge this July resulted from frequent incidence of 5-day mean ridges in this area (fig. 5). If the ridge occurrences at 60° N. for two 10° longitude bands are combined, we find that 5-day mean ridges were observed in July 1959 80 percent of the time between 155° E. and 175° E., compared with only 23 percent during the Julys of 1947–55.

The other aforementioned 30-day mean troughs and ridges were unusually placed to a similar degree. Note that the 30-day mean trough line in the central Pacific fell in a region of minimum trough frequency and in western Alaska passed through an area of zero trough frequency [6]. This July 5-day mean troughs were located at 60° N. in the 30° longitude band between 175° W. and 145° W. 100 percent of the time, compared to only 31 percent during July 1947–55. The 30-day mean ridge and trough in the United States each was located in an only slightly more favored area. The common situation in July is for a continental anticyclone to persist over central United States, but this July a 5-day mean trough was located at 40° N. between 105° W. and 85° W. 78 percent of the time (to be compared with 20 percent during the 1947–55 period).

It should be noted that the 30-day mean troughs and ridges (fig. 1) were located very close to the regions of high incidence of 5-day mean troughs and ridges, with minor exceptions in Asia (fig. 5), implying a good deal of stability in the general circulation during the month.

However, the mean circulation (fig. 1) differed in several aspects from that of June 1959 [4]. During June an exaggerated summertime pattern, with a ridge over central United States and a trough along each coast, was established. That this trend did not continue into July is attested by the anomalous height falls in central United States, flanked by rises of more than 200 ft. off the New England and Washington coasts (fig. 7). Although it is difficult to determine how or where these changes originated, they were accompanied by a train of height change centers extending upstream in the westerlies to about 120° E. In July 1958 the trough in central United States was likewise associated with abnormally located troughs and ridges as far upstream as Siberia [2].

Figure 8 is the 700-mb. 15-day mean height change from the first half to the last half of July 1959. During July there was considerable filling of the Arctic Low in the Beaufort Sea. In middle latitudes over the Pacific the perturbations intensified as falls occurred in the Siberian and Pacific troughs concurrent with rises in the adjacent ridges. Some retrogression of the western North American ridge is indicated by the large rise center, at 140° W., west of the ridge. In North America the trough

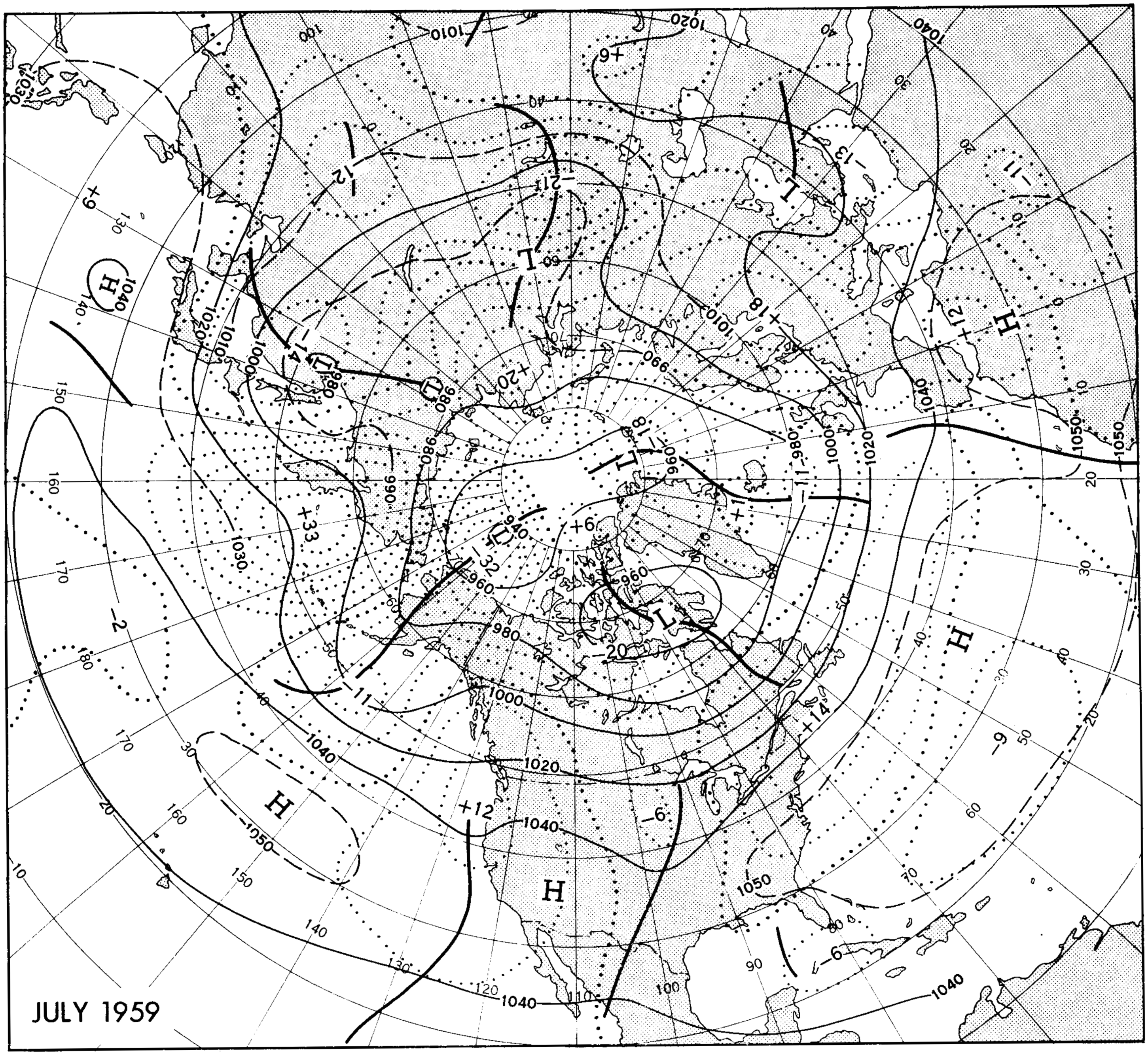

FIGURE 1.—Mean 700-mb. contours (solid) and height departures from normal (dotted), both in tens of feet, for July 1959. Many of the troughs and ridges were located in climatologically unfavored areas.

filled in the north but intensified over the Southern Plains States as July progressed. Over Europe an incipient block is discernible.

The 700-mb. 30-day mean jet stream (fig. 9) was rather ill-defined and displaced north of its normal position in many longitudes. This northward shift produced above normal wind speeds over Canada, but in the United States wind speeds were near to below normal. Negative departures along the east coast and in the western Atlantic (fig. 9B) reflect the easterly regime which prevailed in that area. Speeds were also well below normal in the western Pacific.

The largest monthly height anomalies, a +330 ft. and −320 ft. couplet, were associated with the Bering Sea ridge and a deep Arctic Low over the Beaufort Sea (fig. 1). This configuration produced a super-normal northwesterly flow over the Bering Strait, which brought cool thicknesses (1000–700 mb.) to much of Alaska (fig. 6), quite similar to March 1959 [3] when many places in Alaska reported record cold. Over the United States

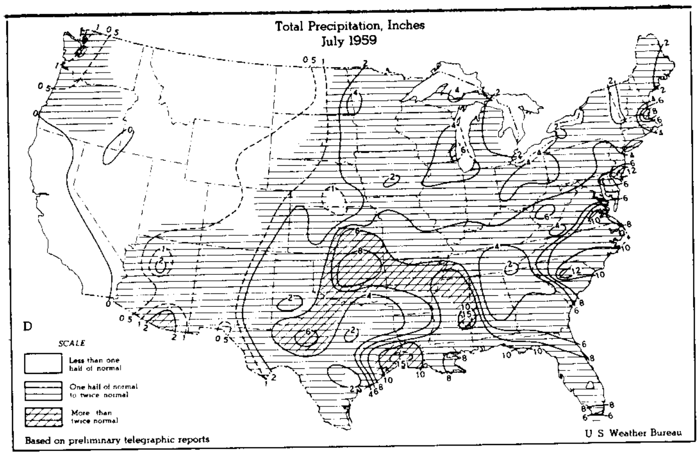

Figure 2.—Total precipitation (inches) for July 1959. Bulk of rainfall was east of the 30-day mean trough. (From [10] Aug. 3.)

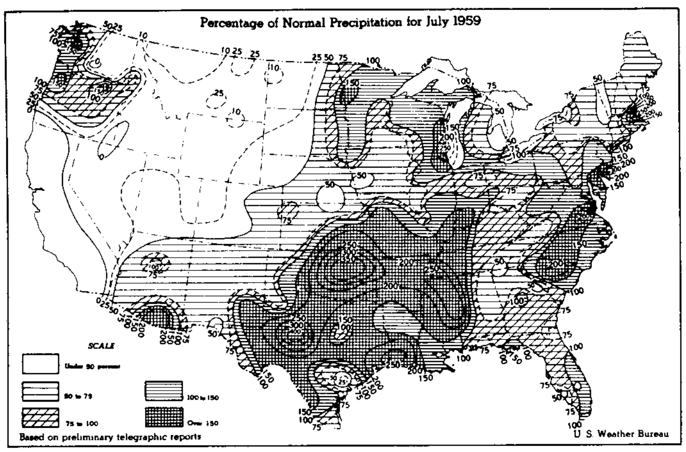

Figure 3.—Percentage of normal precipitation for July 1959. Rainfall was abnormally heavy in the South-Central and Middle Atlantic States but light in the northern Rocky Mountains. (From [10] Aug. 10.)

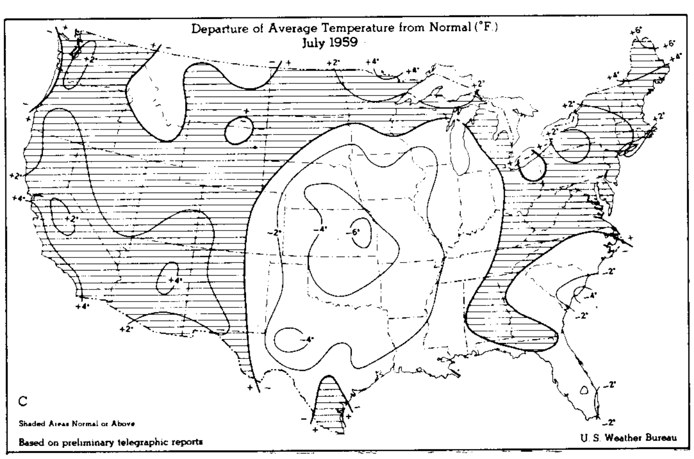

Figure 4.—Departure of average surface temperature from normal (°F.) for July 1959. Central States were cool, but record heat was observed in Arizona and California. (From [10] Aug. 3.)

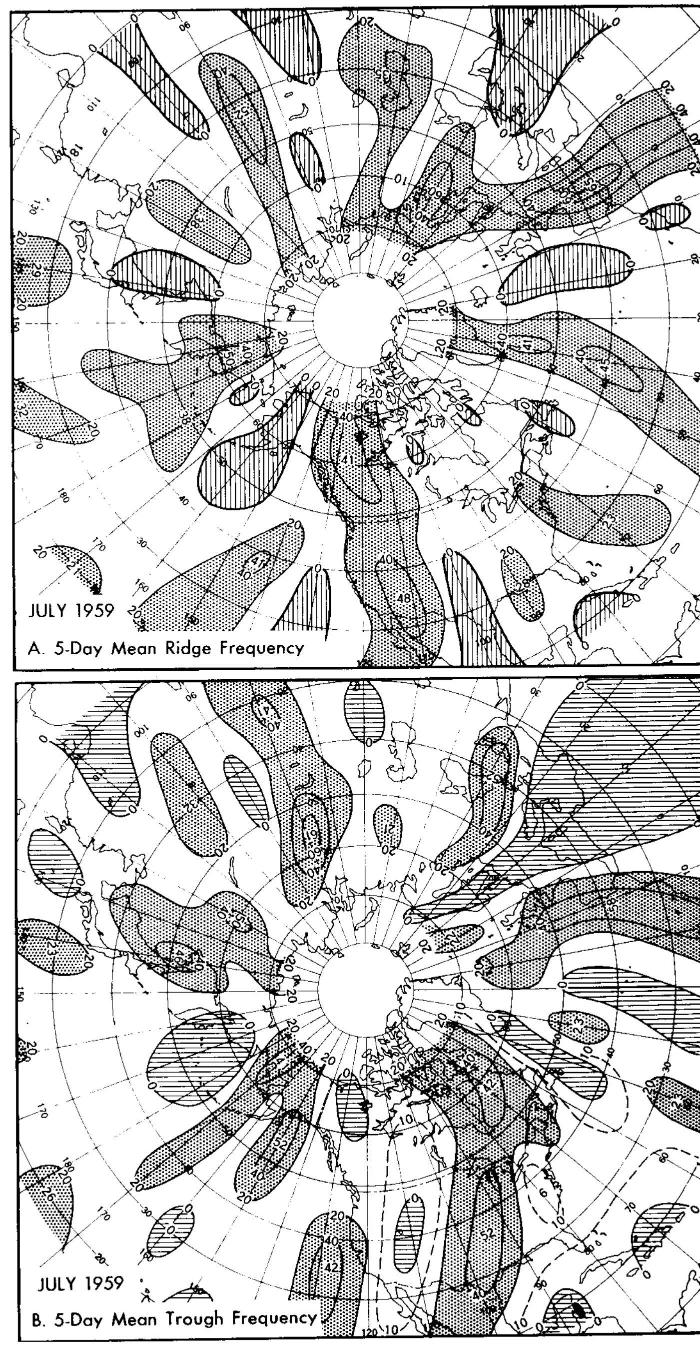

Figure 5.—Percent of the time that (A) ridges and (B) troughs on 5-day mean 700-mb. charts were located within 10° longitude intervals at latitudes from 20° N. to 70° N. for July 1959. The data were adjusted to an equivalent basis with 10° at 50° N. as the unit. Isoline interval is 20 percent; areas with frequency greater than 20 percent are stippled; zero areas are hatched. Note the high frequency of troughs in the central United States and ridges in the Far West.

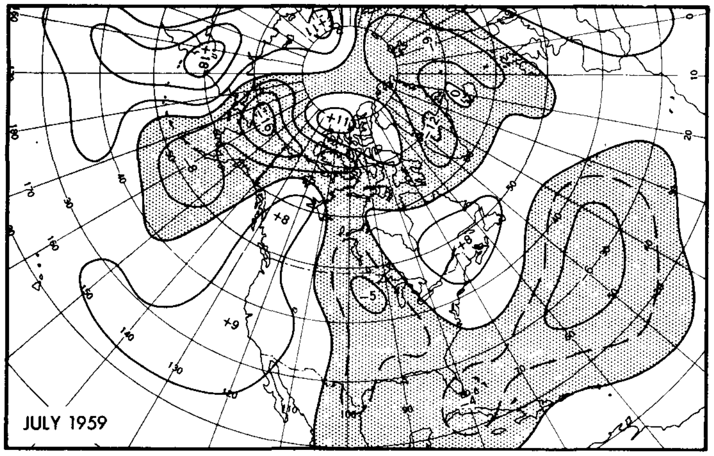

FIGURE 6.—Departure from monthly normal of the mean thickness (700–1000 mb.) for July 1959 in tens of feet. Isoline interval is 50 ft. with intermediate lines dashed. Below normal values are stippled. Pattern is similar to the surface temperature chart (fig. 4) with air masses generally cool in the central United States but warm in the West and Northeast.

height departures from normal, though relatively small, were important in determining the weather anomalies. They were oriented effectively to produce an anomalous, meridional flow across the normal thickness lines (1000–700 mb. [9], generally northerly in the western and southerly in the eastern half of the country.

3. PRECIPITATION AND TEMPERATURE OVER THE UNITED STATES

Except for the showers in Arizona, the bulk of the precipitation fell east of the 30-day mean trough in two rather distinct areas. Record amounts over the Middle Atlantic States were associated with greater than normal easterly and southeasterly flow. This is well indicated by the anomalies of 700-mb. height (fig. 1), wind speed (fig. 9), thickness (fig. 6), and sea level pressure (Chart XI in [8]). Moisture-laden tropical air masses predominated, facilitating convective showers. Much of the rainfall was associated with cold and stationary fronts which were located in this area more than half of the days during July (fig. 10). Very little rainfall was directly related to Lows, which were confined mainly to the higher latitudes (fig. 11B). However, one cyclone, hurricane Cindy, entered the South Carolina coast on July 8. Although it subsequently weakened, it produced copious rainfall along the Atlantic Seaboard from July 8 to 11. New England was north of the anomalous easterlies and was predominantly dry, except for the extreme southeastern part where near record precipitation amounts were reported. Weather, particularly visibility, was unusually bad in Nantucket, Mass., where fog or fog and rain occurred on 27 days of July.

The other major area of rainfall was centered over the Southern Plains and South-Central States. It was associated with the abnormally cyclonic 700-mb. flow (figs. 1, 5) and the anomalous southerly winds in the lower troposphere (fig. 1). No extratropical cyclones were observed in this area, and most rainfall resulted from heavy local shower activity and hurricane Debra. This short-lived, tropical cyclone deepened explosively on the 24th, just off the Texas coast (see Chart X in [8]) and filled rapidly as it moved northward into Oklahoma the next day. Debra produced heavy rainfall in Texas and Louisiana. Galveston, Tex., for example, reported over 5 inches.

West of the 30-day mean trough (fig. 1) and the region of frequent 5-day mean troughs (fig. 5) rainfall was generally light (fig. 3). A broad band of little or no rainfall extending from California northeastward to Montana was associated with persistent anticyclonic circulation and northerly anomalous flow at 700 mb. over the western United States (figs. 1, 5). Record (or near record) dryness was reported at many stations in Colorado, Idaho, Montana, the Dakotas, and Wyoming (table 1–B).

The light precipitation in the northern Appalachian Mountains was consistent with a weak mean ridge over that region (fig. 1), but an explanation for the pocket of light rainfall in the southern Appalachians is not readily extracted from the mean circulation. However, it does correspond with a center of anticyclonic relative vorticity at 700 mb. (not shown). Other interesting precipitation phenomena are listed in table 1.

In the central United States, except along the northern

TABLE 1.—*Abnormal precipitation (inches) for July 1959*

A. HEAVY AMOUNTS			B. LIGHT AMOUNTS		
Station	Monthly total	Remarks	Station	Monthly total	Remarks
Worcester, Mass	8.11	Second wettest July.	Idaho Falls, Idaho	Trace	Record July.
Atlantic City, N.J	15.69	Record month.	Great Falls, Mont	0.04	Do.
Richmond, Va	12.85	Second wettest July.	Havre, Mont	.07	Do.
Greensboro, N.C	9.81	Wettest July since 1927.	Helena, Mont	.11	Do.
Winston-Salem, N.C	10.86	Record July.	Kalispell, Mont	.04	Second driest July.
Memphis, Tenn	8.84	Do.	Sheridan, Wyo	.08	Record July.
Oklahoma City, Okla	8.44	Do.	Bismarck, N. Dak	.41	Second driest July.
Tulsa, Okla	9.85	Second wettest July.			
Port Arthur, Tex	18.69	Do.			
Meridian, Miss	15.29	Record July.			

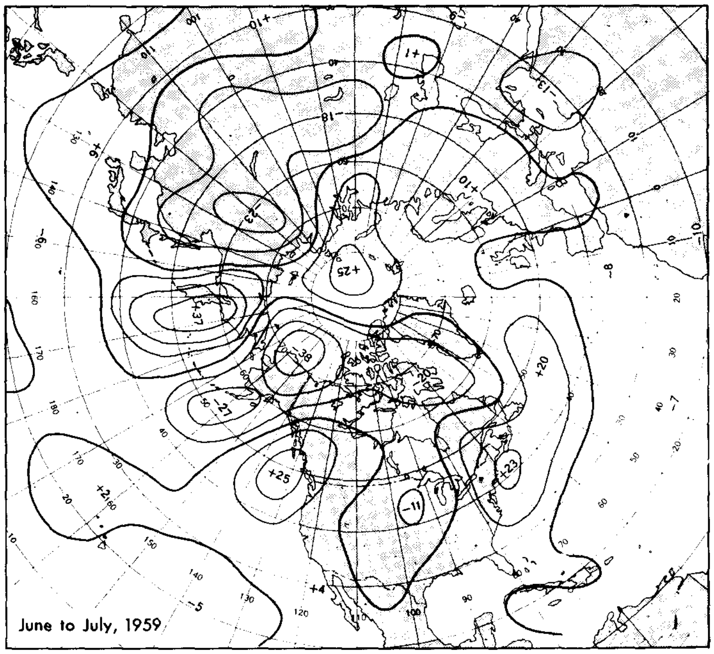

FIGURE 7.—Difference between 30-day mean 700-mb. height anomaly for June and July 1959 (July minus June) in tens of feet. Isoline interval is 100 feet. Over the United States the circulation departed from the common summertime pattern as heights fell (relative to normal) in the center and rose in the West and East.

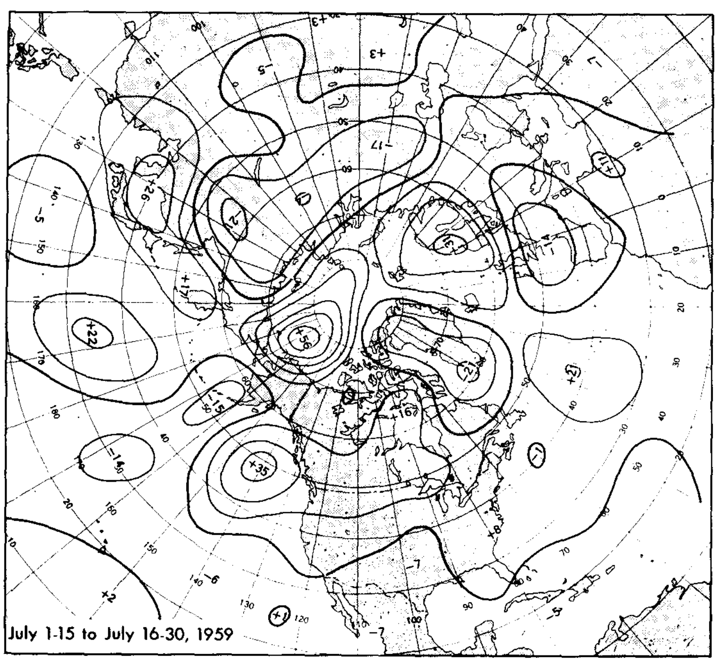

FIGURE 8.—Fifteen-day mean 700-mb. height change from July 1–15 to July 16–30, 1959 (July 16–30 minus July 1–15) in tens of feet. Isoline interval is 100 ft. Height changes were small over North America.

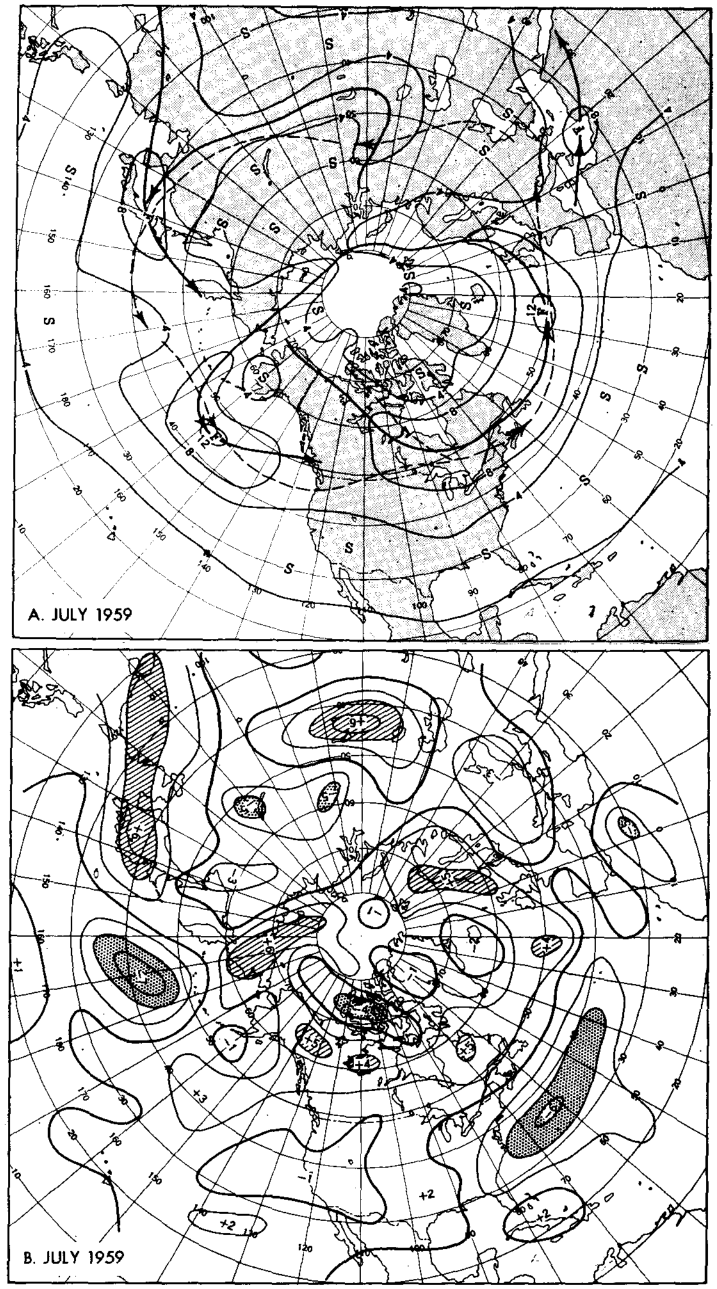

FIGURE 9.—(A) Mean 700-mb. isotachs and (B) departures from monthly normal wind speeds, both in meters per second, for July 1959. Solid arrows in (A) indicate principal axes of maximum winds, and dashed arrows give their normal July positions. Areas with anomalies greater than 4 m.p.s. are stippled. Wind speeds averaged below normal over eastern United States, reflecting the prevailing easterly regime in that area.

border, the weather was cooler than normal (fig. 4). In parts of Texas, Kansas, Nebraska, and Missouri, where temperatures averaged below normal every week [10], monthly anomalies were the largest and mean temperatures approached near record lows (table 2). This was marked cooling, relative to normal, from the previous month [4], and it was as much as four classes colder at

TABLE 2.—*Abnormal surface temperatures (°F.) for July 1959*

Station	Monthly average	Remarks
A. COOL WEATHER		
Midland, Tex.	78.1	Equalled July record.
Topeka, Kans.	74.4	Both cool and wet.
Lincoln, Nebr.	75.1	Do.
B. HOT WEATHER		
Caribou, Maine	69.5	Second warmest July.
Winslow, Ariz.	80.9	Record July.
Yuma, Ariz.	96.7	Record month.
Blue Canyon, Calif.	72.8	Do.
Los Angeles, Calif.	75.1	Do.
San Diego, Calif.	73.7	Record July.
Burbank, Calif.	77.2	Second warmest July.
Mt. Shasta, Calif.	70.8	Do.
Red Bluff, Calif.	85.3	Maximum 100° F. 24 consecutive days.

North Platte, Nebr. (from much above to much below normal) (fig. 12). This cooling was brought about by the replacement of the continental High of June by July's trough, subnormal heights, and northerly anomalous flow at 700 mb. (fig. 1). In this area during the summer mean temperatures are depressed by cloudiness and precipitation, so that heavy rainfall is usually attended by subnormal temperatures. This was true this July, except for a small area around Nebraska where the weather was both cool and dry.

Very warm temperatures were observed in the Northeast where 700-mb. heights were 140 feet above normal (fig. 1); 1000 to 700 mb. thicknesses (fig. 6) and sea level pressures (see Chart XI in [8]) were also above normal. Largest temperature departures were in northern Maine where Caribou, with an average temperature of 69.5° F. which is 5.5° F. above normal, had its second warmest July on record.

Although temperature anomalies in the Southwest were smaller than those in the Northeast, parts of Arizona and California had a record-breaking heat wave (table 2–B). The Weather Bureau station at Yuma, Ariz. reported that "July was a continuation of the record heat wave started in June. The monthly mean temperature of 96.7° F. made this not only the highest in July, but also the highest ever recorded for any month at Yuma. . . . For 30 consecutive days, from June 30th to July 29th inclusive, the minimum temperature was 81° or higher." Incidentally, the maximum temperatures for this July at Yuma averaged 109.4° F. Factors contributing to this heat wave were the weakness of the trough along the west coast and the locally above normal 700-mb. heights (fig. 1) and thicknesses (1000–700 mb.) (fig. 6). Of equal importance perhaps, was the adiabatic warming associated with subsidence underneath the upper-level High and with downslope northerly winds from the interior, as indicated by the 700-mb. chart (fig. 1) and anomalous thermal wind (fig. 6).

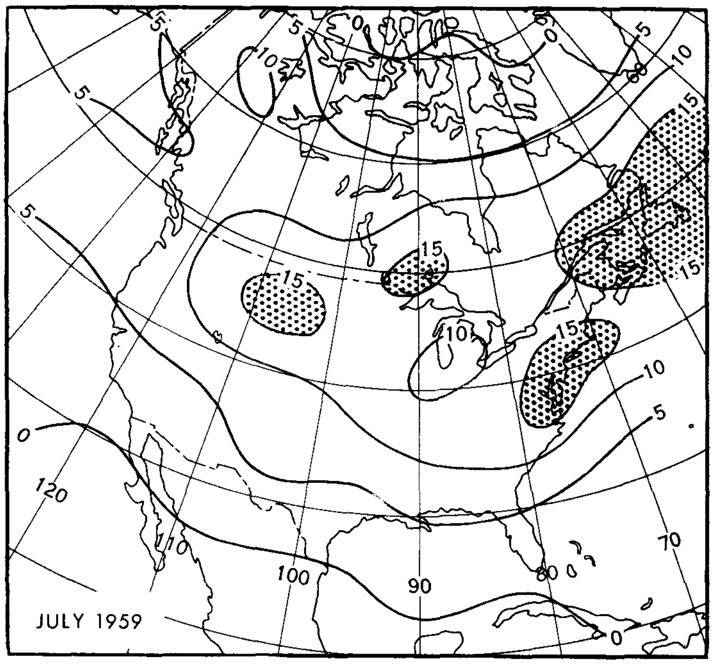

FIGURE 10.—Number of days in July 1959 with fronts of any type within unit squares (with sides approximately 500 miles). All frontal positions are taken from *Daily Weather Map*, 1:00 p.m. EST. Areas with 15 or more days with fronts are stippled. Active fronts were often located in the Middle Atlantic States.

4. CYCLONE AND ANTICYCLONE TRACKS

It has already been pointed out in section 3 that few cyclones affected the United States this July. There were some incipient Lows in the North Central States, but most cyclonic activity was in Canada, north of the mean jet stream (fig. 11B). Lows were common in the central Pacific and eastern Canadian mean troughs.

The principal anticyclone track this July was across central United States somewhat south of (but parallel to) the climatologically preferred path [5]. This deviation from normal was also associated with the unusual 700-mb. circulation and furthered the dry, cool weather in Nebraska and vicinity. Most high pressure centers first appeared in the northern Rocky Mountains as masses of maritime polar air separated from the Pacific anticyclone.

5. POSSIBLE CAUSES OF THE ABNORMAL CIRCULATION

Why did a circulation not climatologically favored prevail over the western Northern Hemisphere for a period as long as a month? What factors were operating to maintain this rarely observed circulation? Mountain effects are difficult to assess, but various heating terms may be estimated using methods similar to those of Wexler [11] and Aubert and Winston [1]. Diabatic heating may be inferred (but with some doubt) from figure 13 which has the 30-day mean thickness lines (700–1000 mb.) superimposed on the mean 700-mb. contours. Where the indicated advection of thickness was large (contours and

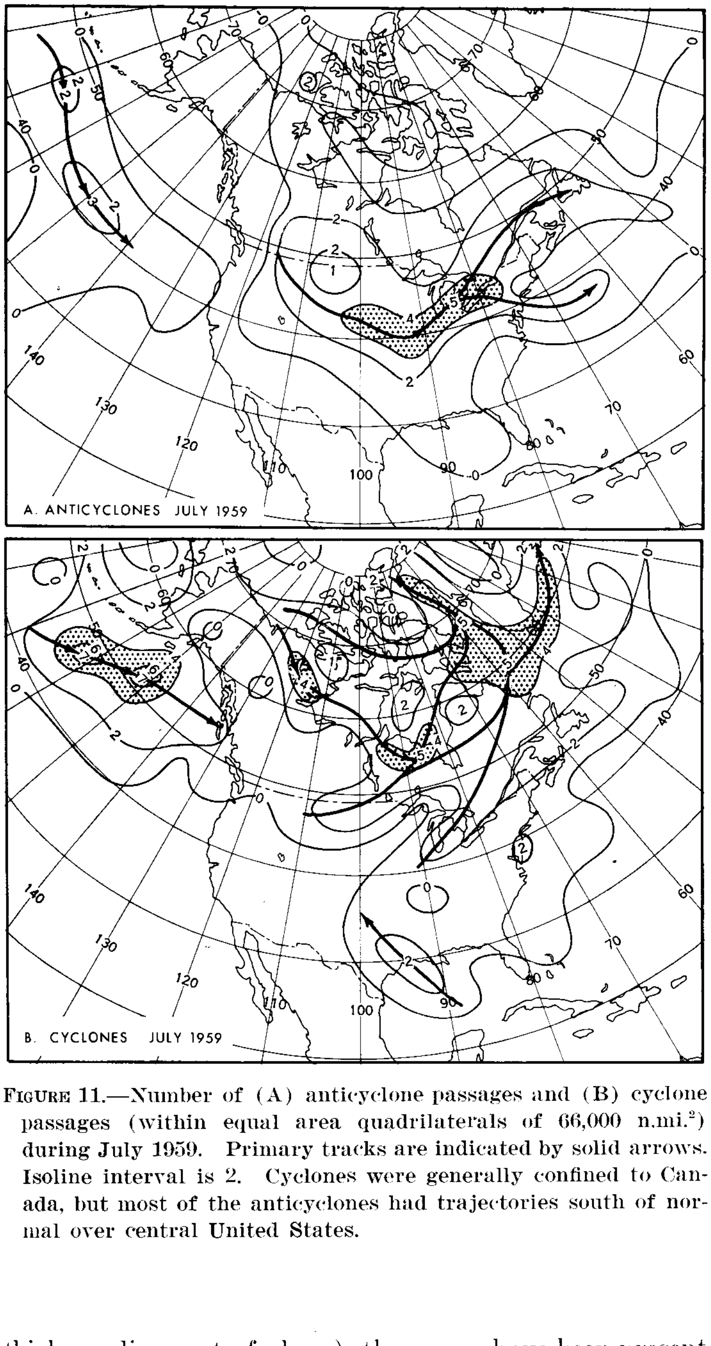

Figure 11.—Number of (A) anticyclone passages and (B) cyclone passages (within equal area quadrilaterals of 66,000 n.mi.^{2}) during July 1959. Primary tracks are indicated by solid arrows. Isoline interval is 2. Cyclones were generally confined to Canada, but most of the anticyclones had trajectories south of normal over central United States.

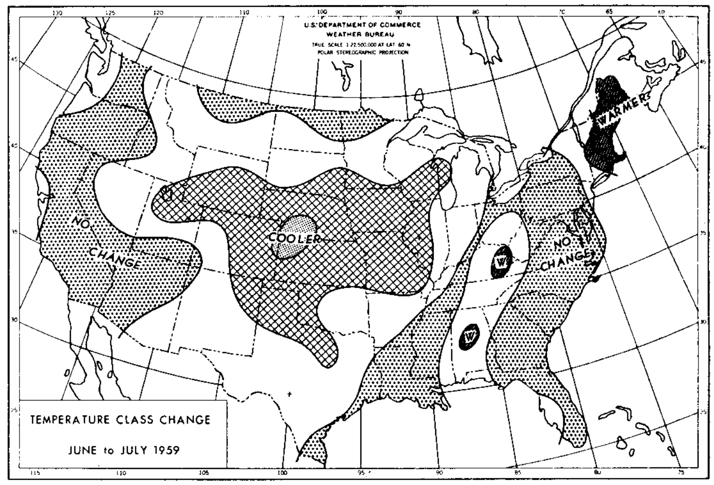

Figure 12.—Number of classes the anomaly of surface temperature changed from June to July 1959. Areas where the anomaly in July was 2 or 3 classes warmer are hatched; 2 or 3 classes cooler, cross-hatched; 4 classes cooler, fine stippled; and areas of no change, coarse stippled. July was cooler than June in the Midwest, relative to normal.

thickness lines out of phase), there may have been present any one of the following three processes: diabatic heating and cooling, adiabatic warming and cooling through vertical motion, and diffusion of heat by the daily eddies. These effects are difficult to isolate, in this instance, but an attempt will be made to deduce the most important one.

The two main regions of indicated advection were over northwestern United States and the western Pacific south of the Kamchatka Peninsula. We are forced to ignore the eddy terms since they are unknown, even though they may be quite large in some areas. As in a previous study [3], the monthly mean vertical motion was approximated by averaging 30 daily values at 600 mb. computed from initial data from the Joint Numerical Weather Prediction Unit's baroclinic model. The vertical motion was found to be small, not greater than ± 1 m./sec. in the two areas just referred to. It should be pointed out that this vertical motion was computed by the adiabatic assumption and perhaps cannot be used to assess heating terms. The cold advection indicated in northwestern United States suggests diabatic heating (fig. 13A). The same is true in the long-period normal (fig. 13B). Aubert and Winston [1] found that western United States was an area where the atmosphere gains heat in July.

In the western Pacific the indicated warm advection suggests diabatic cooling. (This is also the normal situation, but visual comparison of the two charts in fig. 13 reveals that the indicated advection was much stronger than normal this July.) Air ascending at the average rate of 1 mm./sec. and cooling at the dry adiabatic rate would cool 26° C./30 days. The apparent increase in temperature due to horizontal advection in the area is calculated of the order of 100° C./30 days. The net calculated temperature change due to warming by advection and cooling by vertical motion exceeds any possible local temperature change and suggests that diabatic cooling occurred. This cooling would produce anticyclogenesis at sea level downstream from the center of the heat sink [7] and, at least partially, explain the abnormally high pressure observed in the western Bering Sea. A positive sea level pressure anomaly (approximately 8 mb.), quite similar to the 700-mb. height anomaly (fig. 1), was centered at 52° N., 170° E.

Severe criticism may be leveled at this hypothesis because of the drastic assumptions made and the absence of more quantitative work. However, this section was included to focus attention on the observed conditions and to furnish basic material for more complete investigations. Now that computations of vertical motion are routinely available, although based on adiabatic processes, it may be possible to obtain rough quantitative estimates of the diabatic heating.

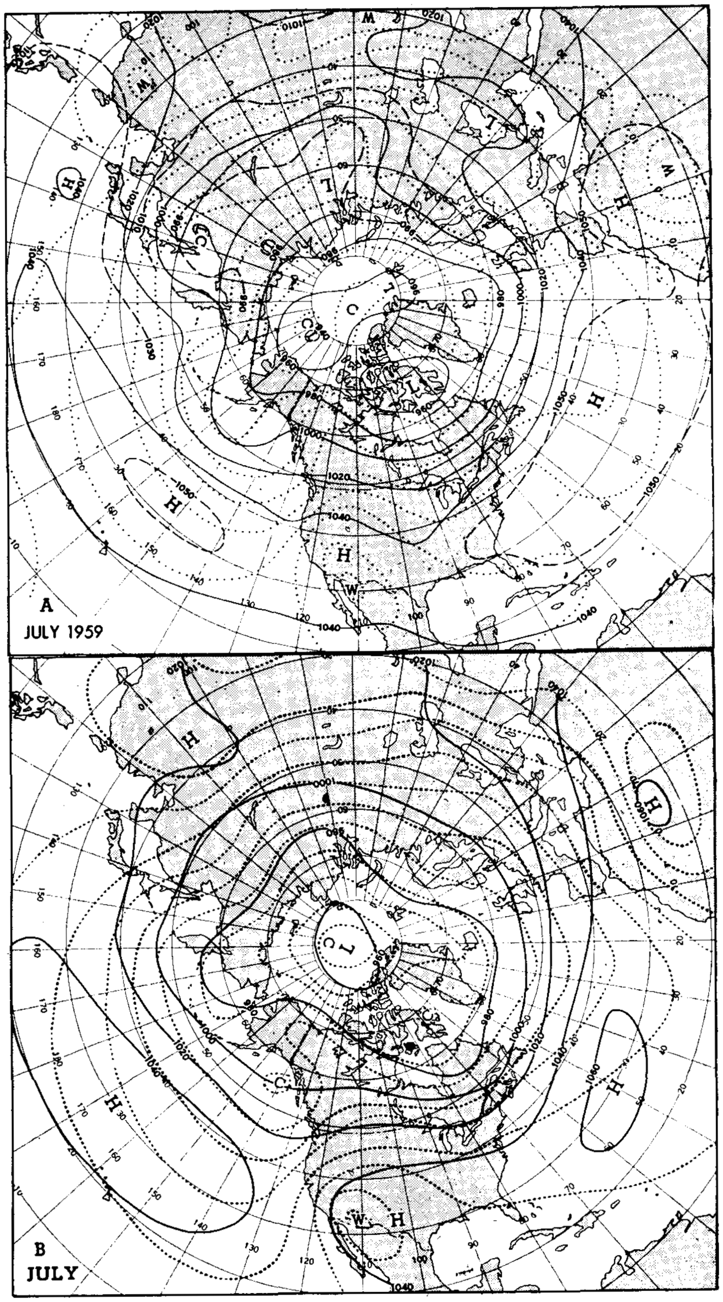

Figure 13.—Mean 700-mb. contours (solid) and thickness (1000–700 mb.) (dotted), both in tens of feet. (A) is for July 1959 and (B) is the July normal chart. 700-mb. contour interval is 200 ft.; thickness isoline interval is 100 ft. This July there was strong indicated advection of thickness (mean virtual temperature) in the western Pacific.

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